Airspace Super Density Operations Precision Scheduling Human In the Loop Simulation Plans

"Plans for ASDO Terminal Area Scheduling and Arrival Management HITL Simulation"

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Outline

- Super Density Operations Vision
- Goals and objectives of scheduling simulation
- Hypotheses
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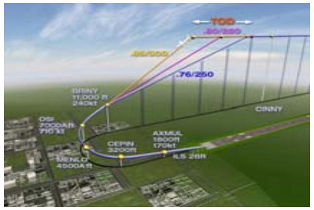
- Simulation Environment Requirements
- Major Development items
- Next-Steps
- Back-up/ Simulation Assumptions

Super-Density Operations Vision

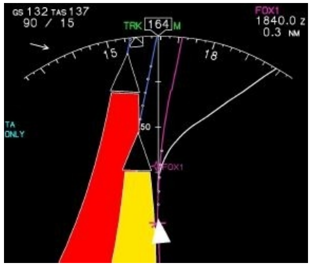
Optimized for single aircraft

- Continuous Descent Arrivals (CDAs) for individual aircraft
  - Efficient arrivals from top of descent to meter fix or runway threshold with other (interfering) traffic



Optimized for multiple aircraft

- CDAs with merging multiple aircraft flows to one airport
  - Using ANSP 4D trajectory management to schedule complex, conflict-free flows to the runway
  - Using Flight Deck merging and spacing capability to enable efficient multiple CDAs/TAs to runway threshold
  - Closely spaced parallel approaches where possible
- Integrated arrival, departure, and surface operations that maximize efficiency and throughput



Optimized for multiple airports

- Integrated arrival, departure, and surface operations including runway balancing for metroplex operations (multiple airports) with efficient airspace allocation

Goals and Objectives

- **Human in the loop evaluation of ASDO scheduling algorithms for supporting initial ASDO functionalities:**
  - **Continuous descent approaches into congested airspace (within a few miles of the final)**
  - **Flight deck merging and spacing**

- **Develop a baseline human in the loop simulation capability for supporting ASDO concept development and evaluation**

NextGen Airspace ASDO Project Objectives:

- **NextGen Airspace project's AS.3.6.03 milestone " Evaluation of single airport operations using medium-term technologies"**

- **For major airports, increase peak runway throughput by 5%, decrease mean flight time during descent by 1 minute, and attain 75% conformance to prescribed trajectories in nominal conditions.**

Hypotheses

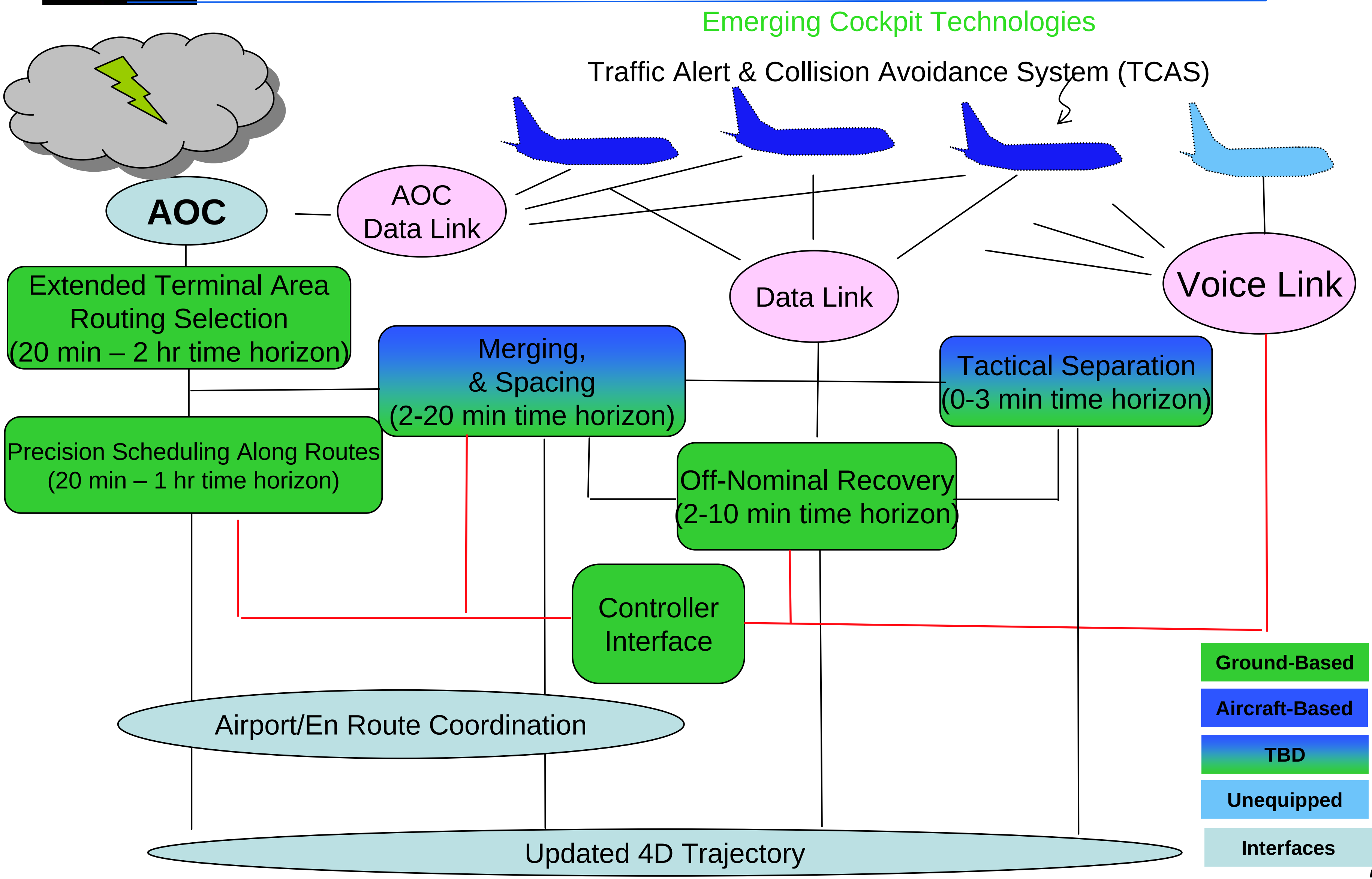
- A team of ANSPs using “mid-term” ASDO technologies:
  - Terminal precision sequencing and scheduling to multiple merge-points
  - ANSP based merging and spacing decision support tools (*controller managed spacing tools*)
  - Flight Deck based merging and spacing decision support tools
  - Flow conditioning (from regional Traffic Flow Management and Separation Assurance technologies)
  - Structured extended and internal terminal routing
  - ASDO procedures

  Can provide safe and high throughput arrival flows from top of decent to landing in the presence of expected regional TFM/SA delivery uncertainties achieving at least 5% greater throughput using fuel efficient decent operations using the JPDO 2006 baseline

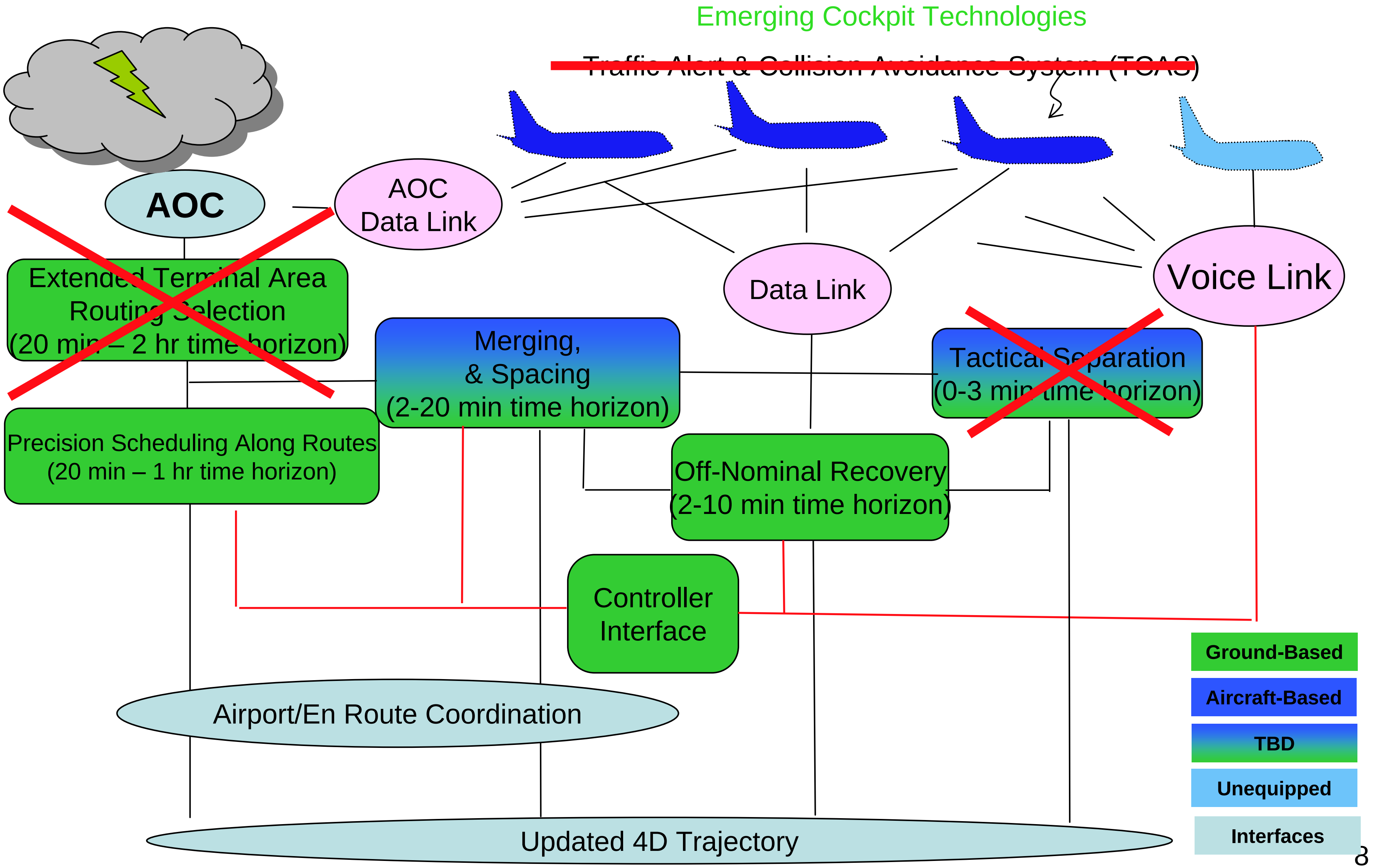
Simplified Con-Ops

- “Scheduler” calculates schedule, sequence, procedure (CDA, time advance, delay) for aircraft arriving into Super Density Operations airport
- ANSP (supervisor/TMC) accepts schedule and notifies ANSP (controller) to use decision support tools (DST) conduct the ASDO procedures
- ANSP prior to TOD provides aircraft with initial ASDO clearance (route and speed) via voice and/or datalink
- ANSP uses the ground based merging and spacing tool to adjust speed via voice clearance as necessary to maintain schedule/sequence conformance and/or delegates spacing to properly equipped aircraft from scheduler boundary to landing (aircraft may progress through as many as 4 ANSPs)
- ANSP either observes or is notified by DSTs of schedule/sequence non-conformance and receives corrective options by off-nominal recovery function
- ANSP provides off-nominal recovery clearances via voice or datalink to reinsert aircraft into flow

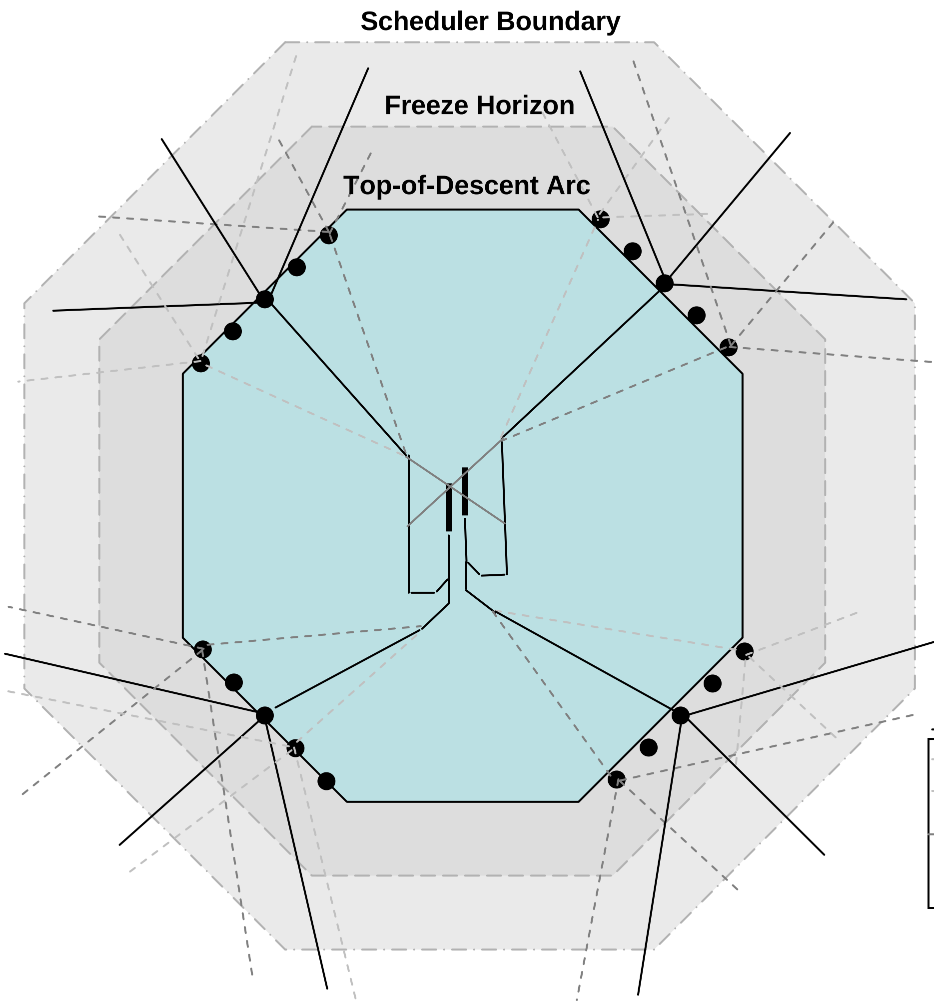
Super Density Operations Architecture

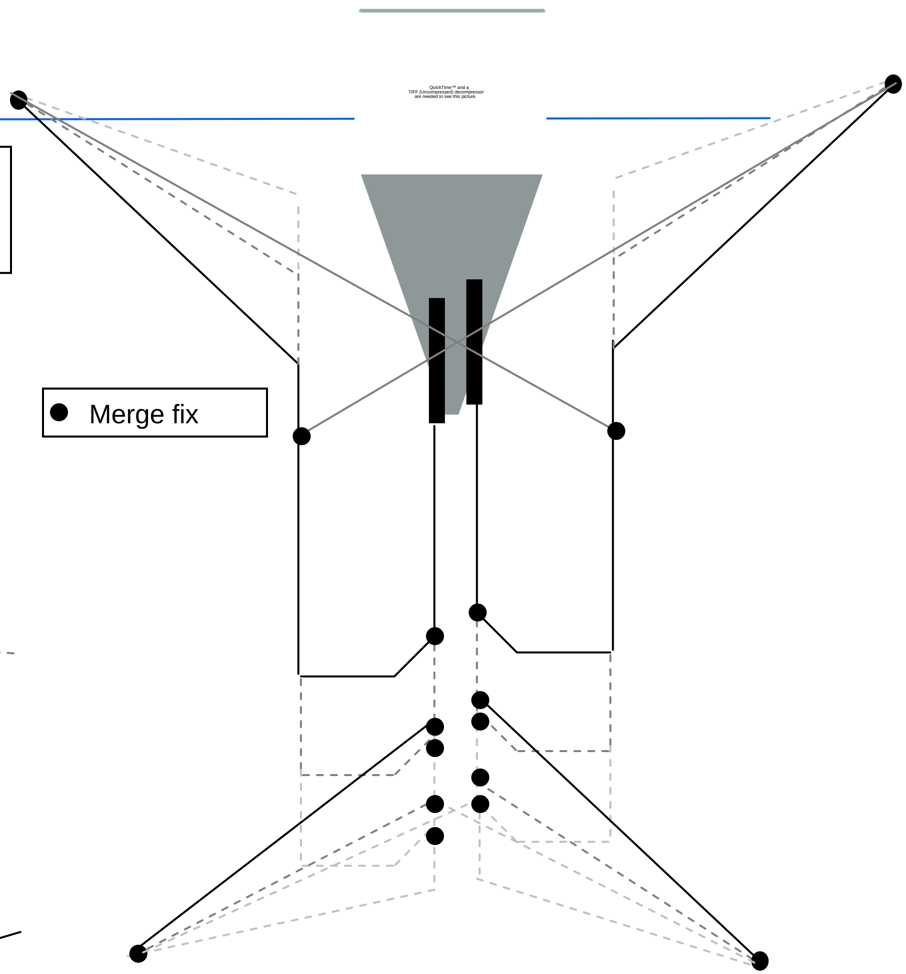


Elements of Super Density Operations for FY2010 Simulation



Primary meterfix routing to nominal terminal area “landing pattern”
Secondary meterfix routing to nominal terminal area “landing pattern”
Tertiary meterfix routing to nominal terminal area “landing pattern”





Primary meterfix routing to nominal terminal area “landing pattern”
Primary meterfix routing to secondary terminal area “landing pattern”
Primary meterfix routing to tertiary terminal area “landing pattern”
Over the top meterfix routing to terminal area “landing pattern”

Scheduler Requirements

Operational Capabilities

1. Build upon TMA functionality and procedures
    1. Multiple merge point scheduling, sequencing and de-confliction
    2. Time advance (moving flows of aircraft ahead)
    3. Possible constrained position shift (priority select efficient sequence patterns)
2. Schedule and sequence to merge points will be generated for a defined arrival route given the landing pattern options for that route (path stretching options) and the degree of speed controllability for an individual aircraft
    1. Allocates delay between top of descent arc, merge points and threshold and from top of descent arc and scheduler freeze boundary.
    2. Maximum delay to be absorbed inside the Top of Descent Arc pre-determined for aircraft type and routing distance.
    3. Delay can be absorbed/reduced through
        1. Speed control inside the Top of Descent Arc (Note: speed control for aircraft on CDA will differ from aircraft not on a CDA)
        2. Selection of specific landing pattern route
3. Scheduler will consider a predefined route to alternate runway when demand exceeds capacity for preferred runway (i.e delay begins to exceed an acceptable limit)
4. Schedule to be frozen prior to top of descent arc (approximately 15 minutes or 100 miles to Top-of-Descent Arc, notional)
5. Scheduler boundary will be at least 30 minutes or 200 miles before Top of Descent Arc
6. Prior to schedule freeze, scheduler automatically adjusts schedule at runway thresholds and merge points based upon delay allocation and arrival traffic
7. If aircraft delay at Top of Descent Arc exceeds delay that can be absorbed through speed control between scheduler boundary and merge points, it is held at scheduler boundary.
8. A reschedule can only be initiated by the ANSP.

Scheduler Requirements (Cont.)

Inputs

1. Arrival routes (Including alternate routes to other runway) pre-defined
2. Arrival rates for each runway – pre-defined
3. Delay allocation inside and outside of the Top of Descent Arc – pre-defined
4. Arrival traffic with definition of preferred runway and approach procedure (CDA or non-CDA) – From test scenario
5. Holes (time and distance) in the schedule – From ANSP
6. Discrete for reschedule – From ANSP

Outputs

1. STAs at threshold and all merge points – To merging and spacing tool and ANSP
2. Arrival route including specific landing pattern as a function of flight number – To merging and spacing tool and ANSP
3. Delay to be absorbed by each flight – To merging and spacing tool and ANSP
4. CDA flights that need to be modified and definition of modification - ANSP

Merging and Spacing Requirements

Operational Requirements:

Merging and spacing clearances can be: 1) provided manually via advisories (CBMS), 2) delegated to ground based automation (GBMS), or 3) delegated to the flight deck (FDMS)

1. **Build upon Controller Managed Spacing Technologies**
2. **Ground Based Merging and Spacing**
    1. **Includes a conformance monitoring function: Conformance will be defined as 3D conformance (on-route and altitude) and ability to meet the STA at designated merge points while maintaining acceptable separation between the leading aircraft and trailing aircraft in trail and at merge points.**
    2. **When conformance can be maintained through speed control, provides suggested speed clearances to meet scheduling/sequencing and merging requirements or provide the flight deck with the STAs for use as an RTA in the flight management system for merging and spacing *(The use of STAs or speed and constrained route clearances will be a simulation test variable.)***
    3. **When conformance cannot be maintained through speed control, identify the problematic aircraft and provides notification to the Off-Nominal Recovery Function**
    4. **Can be used automatically (GBMS) with advisory data-linked to the flight deck, as advisories for controller-based merging and spacing (CBMS), or to infer result of FDMS**
3. Flight Deck Merging and Spacing - see Baxley briefing

Merging and Spacing Requirements (cont.)

Inputs

1. Designation of merging and spacing authority as a function of flight (i.e CBMS, GBMS, or FDMS) – From the ANSP
2. Schedule and sequence to each merge point – from scheduler
3. Flight track data:
    1. Route, procedure, position, velocity, and aircraft type for all scheduled flights – From traffic simulation
    2. Track data for other aircraft in proximity (Outside the meter fix) – From traffic simulation
4. Ability for controller to set speed or accept computer generated speed

Outputs

1. Merging and spacing authority (CBMS, GBMS, or FDMS) – To ANSP
2. Merging and spacing advisories – To ANSP
    1. Speeds for flights needing adjustment to maintain conformance
    2. Identification of aircraft needed to be taken off schedule in order to maintain conformance – To Off-Nominal Recovery Function and ANSP

Off-Nominal Recovery Requirements

Operational Requirements

1. **Provide clearance (procedure based) to safe area**
2. **Define options for reinsertion of non-conforming aircraft from safe area into traffic sequence**
   1. **Automatically calls “what if sequencing and scheduling function” which works with a recovery route planner (Procedurally based) to identify conflict free opportunities for reinsertion of aircraft currently in “safe area” into traffic flow.**
   2. **Examples of “Safe Areas”**
      1. **Missed approach procedure would take aircraft to a pre-designated “safe area”**
      2. **Controller could issue clearance for non-conforming aircraft to a pre-designated “safe area”**
      3. **Fly high along route until breakout to pre-designated “safe area”**

Off-Nominal Recovery Requirements (cont.)

Inputs

1. Airspace definition, off-nominal recovery procedures and safe areas
2. Identification of aircraft to be removed from current schedule – From Merging and Spacing Function (non-conformance)
3. "What if scheduler" requires same inputs as scheduler
    1. Arrival routes (Including alternate routes to other runway) – From test scenario
    2. Arrival rates for each runway – From test scenario
    3. Delay allocation inside and outside of the Top of Descent Arc – From analysis
    4. Arrival traffic with definition of preferred runway and approach procedure (CDA or non-CDA) – From test scenario
    5. Holes (time and distance) in the schedule – From ANSP
    6. Discrete for reschedule – From ANSP

Outputs

1. Identification of candidate solutions
    1. Proposed recovery sequence –To merging and spacing function and ANSP
    2. Decision metrics to aid controller in selecting preferred option (e.g. Delay impact)– To ANSP
    3. Definition of recovery route – To ANSP
    4. Ability to view proposed solution – To ANSP

ANSP Interface

Operational Requirements:

1. Provides a display that allows the ANSP to maintain overall situational awareness and to provide the interface between the ground based automation and the flight deck required in supporting the scheduling and sequencing, merging and spacing, and off-nominal recovery functions as described in the technology requirements for those functions.

System Inputs:

1. As specified in the outputs of the other functions

ANSP inputs:

1. Designate CBMS or FDMS – From ANSP
2. Accept/reject scheduler, merging and spacing or off-nominal recovery recommendations – From ANSP
3. Initiate a reschedule – From ANSP

Outputs:

1. Traffic situational awareness display/displays – To ANSP
    1. ANSP designated Merging and Spacing authority
    2. Speed Advisories
    3. Off-Nominal Recovery options
2. ANSP selected speeds – To ANSP for transmittal to flight deck
3. ANSP selected off-nominal recovery option – Schedule modification to Scheduler Function , recovery route to ANSP for transmittal to flight deck

Simulation Environment Requirements

- **Location**
  - **ASDO procedure enhanced LA Center and SoCal TRACON**
- **Positions**
  - **LA Center arrival high/low (8)**
    - **ERAMS modeled**
  - **SoCal TRACON LAX feeder and final (4)**
    - **STARS modeled**
  - **ANSP scheduler operator**
- **Scenarios**
  - **2006 JPDO/SLDAST baseline peek demand for LAX, including departures, crossing flights**
  - **Approximately 1 hour of demand data**
  - **5%, 10%, and 20% traffic growth on LAX arrivals**
  - **Off-nominal conditions**
    - **“go-around”**
    - **Lost communication**
    - **Incorrectly modeled terminal winds (below 5,000 feet)**
  - **Traffic pre-conditioned with variable level of expected TFM statistical uncertainty on each of the 4 traffic scenarios (flow preconditioning)**

Test Matrix/Simulation Runns

- **8 scenarios repeated 3 times with 2 sets of test subjects (SMEs)**
  - **48 runs**
  - **3 training runs/test subject group**
  - **54 total runs (27/team)**
- **4 runs/day possible**
  - **1 hour/run**
  - **30 min debrief/questionnaire/run**
  - **2 runs am, 2 runs pm**
- **SME test subjects weekly plan**
  - **Monday (half day) brief simulations and procedures and 1-2 training runs**
  - **Tuesday (full day) 4 runs (1-2 training, 2-3 test conditions)**
  - **Wednesday (full day) 4 runs (test conditions)**
  - **Thursday (full day) 4 runs (test conditions)**
  - **Friday (half day) 2 runs (test conditions)**
  - **Optimistically 21/27 required runs per week**
  - **Realistically ~14-18/27 runs per week**

Data Collection

- **Qualitative**
  - **Controller Acceptance Rating Scale (CARS)**
  - **Workload assessment scale during simulation**
  - **Questionnaire**
- **Quantitative**
  - **Schedule sequence conformance**
  - **Separation violations**
  - **Throughput**
  - **Delay**
  - **Number of clearances**
    - **Speed changes**
      - **Commanded**
      - **Executed**
    - **Number of ANSP improvised clearances**
      - **Improvised vectoring**
      - **Sequence shift**
  - **Energy efficiency**

Major development items

- Scheduler (enhanced TMA)
- Ground Based Merging and Spacing function (build on Controller Managed Spacing and EDA speed control functionality)
- Off-nominal recovery function(completely new)
- ANSP interface (build on MACs)
  - Scheduler position
  - Operator position (controller)
- Simulation environment
  - ANSP side
  - Flight deck side (pseudo-pilot system)
- System development simulations
  1) Simulation environment
  2) scenarios
  3) Scheduler
  4) Ground Based Merging and Spacing function
  5) Off-nominal recovery function
  6) ANSP interface
  7) Integration
- ASDO procedure development
- Data recording and analyses capability
- Test plan development
- ASDO-Simulation development paper
- Recruit SMEs

Next Steps

- Gap assessment of required functionalities
- TMA Scheduler Algorithm enhancement
  - Multiple merge sequencing and scheduling
  - Time advance
  - Constrained position shift
- Degree-of-freedom as a function of route and vehicle type analyses
- Simulation Environment development
- Development, testing, development, testing…etc.
- Initial Simulations to begin in the February timeframe with full functionality by Summer of 2010

Back-up

- Questions??

Simulation Assumptions

- **Environmental Assumptions**
  - **Single airport**
  - **Closely spaced but independent parallel runways**
  - **Low visibility/IMC operations – No convective weather**
  - **Human Centric Ground Based Automation**
  - **CDA approaches in place as conditions allow**
    - **CDA down to some fixed (distance prior to glide-slope intercept**
    - **Standardized approach from 3000 feet to touchdown**
  - **Current High End Flight Deck + FDMS + CDTI + RTA + Data Link (FANS or Similar SOA Protocol)**
- **ASDO Simplifications**
  - **Extended terminal area routing scripted between threshold and scheduling boundary (Approximately 200 miles beyond an arc that would define the region in which all CDA top of descents would be included (Top of Descent Arc))**
    - **Set of predefined fixed routes to "Landing Pattern" in normal conditions**
    - **Constrained route flexibility within "Landing Pattern"**
    - **Constrained flexibility in missed approach and off-nominal recovery procedures**
  - **Meter fix will be defined at Top of Descent Arc**
  - **Speed is the only inner loop mechanism of control (i.e. no path stretching other than the constrained flexibility used in developing the schedule)**
  - **Traffic will be seeded on the scripted routes at the scheduling boundary based on time with an uncertainty that can be varied. The traffic will be randomly distributed based on aircraft type preferred runway, and equipage (Data Link, FDMS). The uncertainty will be adjusted to assure traffic is sufficiently organized that the STA at the meter fix can be met by speed control alone with a high degree of probability**
- **No arrival route negotiations between crew and ANSP.**
  - **The basic functions included in the 2010 simulation may allow this but are not currently included in the experiment plan or story board.**

Note; "Landing Pattern" is used to identify a region of airspace immediately surrounding the airport where the routes are parameterized within a generalized traffic patterns

Research Questions

- Use of RTAs versus speed and constrained clearances for traffic de-confliction
- Use of FDMS versus ground-based speed and constrained route clearances for precise spacing
- Human automation interaction
  - When traffic is within scheduler control authority guidelines
  - When traffic is not within scheduler control authority
    - Recovery planning
    - Triggering a reschedule